Sociability increases survival of adult female giraffes

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Abstract: Studies increasingly show that social connectedness plays a key role in determining survival, in addition to natural and anthropogenic environmental factors. Few studies, however, integrated social, non-social and demographic data to elucidate what components of an animal's socio-ecological environment are most important to their survival. Female giraffes (Giraffa camelopardalis) form structured societies with highly dynamic group membership but stable long-term associations. We examined the relative contributions of sociability (relationship strength, gregariousness and betweenness), together with those of the natural (food sources and vegetation types) and anthropogenic environment (distance from human settlements), to adult female giraffe survival. We tested predictions about the influence of sociability and natural and human factors at two social levels: the individual and the social community. Survival was primarily driven by individual- rather than community-level social factors. Gregariousness (the number of other females each individual was observed with on average) was most important in explaining variation in female adult survival, more than other social traits and any natural or anthropogenic environmental factors. For adult female giraffes, grouping with more other females, even as group membership frequently changes, is correlated with better survival, and this sociability appears to be more important than several attributes of their non-social environment.

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Supplementary Material

Simple Ratio Index of Association

Association indices are used to define edges in a network. They estimate the proportion of time that nodes (individuals) are seen together, and range between 0 and 1, where 0 means two individuals were never seen together, and 1 means two individuals were always seen together. In the simple ratio index, the edge weight is calculated as: $E_{AB} = \frac{x}{x+y_{AB}+y_A+y_B}$, where E = undirected edge weight between individuals A and B, x = number of sampling periods where individuals A and B were observed in the same group, y_{AB} = number of sampling periods in which both A and B were observed but not together in the same group, y_A = number of samples where only individual A was seen, and y_B is the number of samples where only B was seen [1].

Sociability and Social Community Detection

We began with a subsample of all adult females with at least six observations to improve the accuracy of the edge weights [2]. We calculated node-level measures of sociability, including the strength of each female's relationships from her mean and maximum non-zero edge weight, the coefficient of variation of her non-zero edge weights, gregariousness, and betweenness, using packages *asnipe* [3] *igraph* [4] and *sna* [5] for R [6]. See Figure S1 for histograms of the values. A good module division provides many edges within communities and few between and is quantified by a modularity coefficient known as Q [7]. We used the cluster-walktrap community-detection algorithm to divide the adult female giraffe metapopulation into social communities and calculated modularity with package *igraph* [4]. We assessed the robustness of the community assignment using bootstrapping and the metric community assortativity (r_{com}), which

takes into consideration the detectability of associations [8]. We calculated r_{com} with package *assortnet* for R [9].

The cluster-walktrap community detection algorithm parsed the adult female giraffe metapopulation into 14 distinct communities with $Q = 0.742$, demonstrating a relatively high degree of modularity. A bootstrap test indicated the assignments of individuals to communities was robust ($r_{com} = 0.749$). The high Q and r_{com} values suggest strong community structure and high community fidelity with a low tendency for adult females to mix with other communities [8]. We excluded members of four communities that contained <15 individuals, resulting in a sample of 512 adult females in 10 communities for survival modelling.

Non-Social Environmental Covariates

We plotted locations of giraffe group formations on a GIS using ArcMap 10.8 (Environmental Systems Research Institute, Redlands, CA, USA), and extracted at every location natural and anthropogenic environmental variables of vegetation and proximity to nearest human settlements of towns and bomas (Tables S1 and S2; main text figure 1; figure S2 a-b). We used a combination of publicly available remote-sensed data and our own ground-based vegetation surveys to create GIS vegetation features. We mapped two broad vegetation types (figure S2 c-d): (1) deciduous bushland and thicket and (2) edaphic volcanic soils with grassland and scattered woody species [10], derived from a natural vegetation map developed by the University of Copenhagen's Vegetation and Climate Change in Eastern Africa (VECEA) project. We then used ground-based observations that we collected in January 2014 every 2 km along our roads to map polygons of vegetation with >10% cover of one of three primary giraffe forage species: (1) *Vachelia tortilis*; (2) *V. drepanolobium*; and (3) *Dichrostachys cinerea* [11,12,13,14,15]. We used Google Earth (Mountain View, CA, USA) aerial imagery from June

2014 to map bomas as points and towns as polygons. To calculate distances to bomas we used the Point Distance proximity function and to calculate distances to towns we used the Near proximity function in ArcMap. For community-level environmental covariates, we calculated the 95% kernel home ranges using locations from all individuals in each community with the package *adehabitatHR* in R [16]. We then quantified the proportion of vegetation types in the community home range with package *raster* for R [17], and average distances from the centre of the community home range to the nearest boma or town in ArcMap. We also modelled local giraffe population density within the community home range as a covariate, as this is known to influence adult female survival probabilities for some other ungulates [18 but see 19]. Local giraffe population density includes all adult female giraffes ever detected within the home range of the social community, regardless of number of detections or community assignments (N=1139 adult females).

Survival Rates

We estimated apparent survival probabilities and tested hypotheses using capture-recapture methods [20] from individual adult female encounter histories analysed in program MARK 8.2 [21]. We utilized the Pradel robust design model to provide estimates of seasonal apparent survival (S), temporary emigration (γ'' and γ'), and capture and recapture probabilities (p and c) [22,23] and ranked models using Akaike's Information Criterion corrected for small samples (AIC_c). We were unable to conduct surveys in LMNP during the last two primary sampling periods in 2016 due to logistical constraints, so we set p and c to zero for the LMNP community for those periods. We tested a survival model that grouped females from the same social community, because we suspected these females were likely to share common influences and thus there might be potential dependencies among those individuals. To assess support for

community effects in *S*, *p*, and *c*, we considered community-specific parameters denoted (g), as well as constant, equal parameter values for all communities, denoted (.) We always included community effects in immigration (γ') and emigration (γ"). We ranked models to find the most parsimonious structure, beginning with the fully parameterized model in our set with constraints (community effects) on the parameter of interest (*S*), but with both community and temporal effects (g+t+g:t) in capture and recapture rates. Temporal effects mean that capture and recapture rates vary by survey. We also considered that females that tended to be seen with other females more may have higher detectability, so we modelled gregariousness as a covariate to *p* and *c* (g+t+g:t+gregariousness); see figure S3. We ranked all possible combinations of models of community and constant effects.

After selecting the best model of community and constant effects, we added the effects of social and non-social environmental covariates on apparent survival. We examined multicollinearity among covariates by calculating the Spearman correlation coefficient and did not include correlated coefficients (>0.50) in the same model (Table S3). We first ran simple models with a single covariate, including a constant survival model (Table S4). We then ran more complex additive and interactive models with covariates from models that ranked above the constant survival model (Table S5). We also included covariates distance to boma and distance to town in the second model run although these ranked below the constant survival model in the simple model run (Table S4), because we were particularly interested in these anthropogenic effects. All individual covariates were standardized.

We modelled the effects of the following social and non-social environmental covariates on the demographic response adult female survival: (1) average relationship strength [EW]; (2) maximum relationship strength [MAXEW]; (3) coefficient of variation in relationship strengths

[EWCV]; (4) gregariousness [GREG]; (5) betweenness [BETW]; (6) average distance (km) from nearest town (at the individual and community level) [TOWN]; (7) average distance (km) from nearest boma (individual and community level) [BOMA]; (8) proportion of time spent in one of two different broad vegetation types (individual and community level), volcanic soils [VOLC] and dense bushlands [BUSH]; (9) proportion of time spent in stands dominated by one of three preferred giraffe forage species (individual and community level), *Vachelia* (formerly *Acacia*) *tortilis* [VTORT], *V. drepanolobium* [VDREP], and *Dichrostachys cinerea* [DICHRO]; and (10) local giraffe population density (community level) [DENS]. All predictions pertain to both individual- and community-level effects.

Throughout model ranking and selection, we used the logit link function and 2nd part estimation [24]. We considered model AIC_c weights as a metric for the strength of evidence supporting a given model as the best description of the data [25]. There is no goodness-of-fit test of whether the most general Pradel model in our candidate model set adequately fits the data for robust design [24]. Therefore, to test goodness-of-fit, we combined our secondary samples to a simple binary variable (seen, not seen), and treated the resulting encounter history as a live encounters Cormack-Jolly-Seber (CJS) model [24]. We then tested the fit of our data to the fully time-dependent CJS model using Program RELEASE TEST 2 + TEST 3 [26], and median $\hat{c}$ [24].

We detected no strong correlations between social and non-social environmental covariates (Spearman correlation coefficients < 0.50), although several correlations between environmental covariates were significant ($P < 0.05$, see Table S3). We found no evidence for lack-of-fit in the encounter history data (TEST 2 + TEST 3 $\chi^2 = 61.844$, d.f. = 60, $P = 0.41$; median-$\hat{c} = 1.186$), therefore we kept $\hat{c} = 1.0$ for model selection [25].

Exploring Correlations Between Adult Females in Groups, Total Group Size, and Repeatability of Male and Female Counts in Groups

We conducted a post hoc analysis to correlate the number of females in a group and total group size (including adult males, subadults, and calves) and found a simple positive linear relationship between the two ($R^2 = 0.76$; figure S4, top). The same relationship exists between number of adult females in a group and total number of adults and subadults (no calves: $R^2 = 0.78$). There was no significant positive relationship between number of adult females and the ratio of juveniles (calves and subadults) in a group ($R^2 = 0.006$; figure S4, bottom), thus each group has approximately the same ratio of adult females to juveniles regardless of the number of adult females in the group.

We also analysed repeatability of the count of males and females in a group for each female, to determine whether the number of males correlates with number of females. We correlated the random effects from intercept-only generalized linear mixed effects models with a Poisson error distribution (link = "log" with female identification as random effect, and number of adult males in a group as the dependent variable in the first model and the number of adult females in the group in the second model). We then correlated the random effects of the two models and found the male and female group sizes experienced by a female were correlated ($r = 0.57$). On average the repeatability for each female of the number of other females in her group ($= 0.11$) was more than twice as high as number of males in her group ($= 0.04$).

Table S1. Mean, standard deviation, minimum and maximum values of non-social environmental covariates of apparent survival probabilities for 512 adult female Masai giraffes in the Tarangire Ecosystem, northern Tanzania, 2012–2016.

	Distance to boma	**Distance to town**	**Proportion dense bush**	**Proportion volcanic**	**Proportion *V. drepanolobium***	**Proportion *V. tortilis***	**Proportion *D. cinerea***
Mean	5.73	12.06	0.12	0.39	0.11	0.48	0.12
SD	4.39	7.96	0.23	0.44	0.18	0.36	0.19
Minimum	0.48	2.47	0	0	0	0	0
Maximum	21.26	34.91	1	1	0.83	1	1

Table S2. Community-level mean, standard deviation, and range of non-social environmental covariates of apparent survival probabilities for 512 adult female Masai giraffes in 10 social communities the Tarangire Ecosystem, northern Tanzania, 2012–2016.

	Distance to boma	**Distance to town**	**Proportion dense bush**	**Proportion volcanic**	**Proportion *V. drepanolobium***	**Proportion *V. tortilis***	**Proportion *D. cinerea***
Comm 1	4.99 (2.87)	24.74 (4.73)	0.10 (0.13)	0.02 (0.07)	0.01 (0.04)	0.33 (0.22)	0.04 (0.07)
	0.48–9.42	15.90–34.91	0–0.50	0–0.40	0–0.17	0–0.86	0–0.22
Comm 2	12.63 (1.79)	14.56 (4.46)	0.60 (0.18)	0	0	0.83 (0.14)	0
	8.24–15.45	5.96–20.81	0.22–1	0	0	0.43–1	0
Comm 3	9.52 (1.44)	17.52 (3.63)	0.04 (0.08)	0.02 (0.06)	0.02 (0.06)	0.50 (0.28)	0.004 (0.02)
	5.87–11.38	10.95–24.03	0–0.33	0–0.25	0–0.30	0.07–1	0–0.11
Comm 4	3.41 (0.68)	6.18 (1.06)	0.001 (0.01)	0.93 (0.11)	0.20 (0.12)	0.18 (0.12)	0.25 (0.10)
	2.07–5.33	3.73–9.07	0–0.08	0.46–1	0–0.50	0–0.50	0–0.50
Comm 5	2.37 (0.90)	6.87 (1.63)	0.06 (0.08)	0.32 (0.34)	0	0.83 (0.17)	0.05 (0.07)
	0.96–5.07	3.50–11.43	0–0.29	0–1	0	0.47–1	0–0.25
Comm 6	14.10 (2.90)	29.39 (2.81)	0.34 (0.31)	0	0.03 (0.07)	0.31 (0.14)	0.03 (0.06)
	10.81–21.26	22.88–33.64	0–1	0	0–0.29	0–0.67	0–0.24
Comm 7	2.55 (1.30)	11.23 (2.34)	0.03 (0.08)	0.78 (0.25)	0.004 (0.02)	0.34 (0.22)	0.13 (0.10)
	1.18–6.67	5.90–14.90	0–0.40	0.08–1	0–0.10	0–0.77	0–0.31
Comm 8	3.57 (0.66)	4.24 (0.98)	0.004 (0.02)	0.81 (0.23)	0.52 (0.16)	0.04 (0.05)	0.15 (0.12)
	2.37–5.07	2.47–7.38	0–0.15	0.11–1	0.11–0.83	0–0.15	0–0.58
Comm 9	2.76 (0.52)	5.42 (0.85)	0.01 (0.03)	0.97 (0.09)	0.13 (0.15)	0.17 (0.15)	0.55 (0.22)
	1.54–3.62	3.57–9.19	0–0.15	0.46–1	0–0.63	0–0.55	0.14–1
Comm 10	3.37 (0.62)	11.99 (1.41)	0	0	0.06 (0.10)	0.92 (0.12)	0.001 (0.01)
	2.17–5.29	9.29–16.90	0	0	0–0.40	0.50–1	0–0.07

Table S3. Spearman's correlation coefficients between social and non-social environmental covariates for analysis of survival of 512 adult female Masai giraffes in the Tarangire Ecosystem, Tanzania (2012–2016). Strong correlations (≥0.50) in bold.

	Average edge weight	Maximum edge weight	Edge Weight CV	Gregariousness	Betweenness	Distance to boma	Distance to town	*V. drepanolobium*	*V. tortilis*	*D. cinerea*	Dense bushlands	Volcanic grasslands
Average edge weight	1											
Maximum edge weight	**0.54**	1										
Edge weight CV	**-0.69**	0.08	1									
Gregariousness	**0.90**	**0.50**	**-0.63**	1								
Betweenness	0.17	-0.17	**-0.50**	0.14	1							
Distance to boma	0.16	0.23	0.11	0.14	-0.13	1						
Distance to town	-0.17	0.14	0.43	-0.16	-0.07	**0.57**	1					
V. drepanolobium	0.11	-0.08	-0.26	0.16	0.02	-0.08	**-0.55**	1				
V. tortilis	0	0.06	0.11	-0.05	-0.10	0.05	0.31	**-0.59**	1			
D. cinerea	0.09	-0.12	-0.29	0.14	0.15	-0.39	**-0.58**	**0.50**	**-0.60**	1		
Dense bushlands	0.12	0.23	0.15	0.10	-0.12	0.42	0.43	-0.38	0.28	-0.35	1	
Volcanic grasslands	0.10	-0.16	-0.38	0.10	0.20	**-0.52**	**-0.77**	**0.53**	**-0.61**	**0.80**	-0.44	1

Table S4. Model selection results for constant survival, community effects, and single-covariate social and non-social environmental models of apparent adult female survival probabilities among 10 communities of Masai giraffes in the Tarangire Ecosystem, northern Tanzania, 2012–2016 (n = 512 females). Bold are models ranked higher than the constant survival model $S(.)$.

Model[a]	AIC_c	ΔAIC_c	AIC_c Weights	Model Likelihood	Num. Par
{*S*(BETW) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	**17277.89**	**0.000**	**0.309**	**1.000**	**468**
{*S*(GREG) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	**17278.79**	**0.906**	**0.197**	**0.636**	**468**
{*S*(VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	**17279.52**	**1.635**	**0.137**	**0.442**	**468**
{*S*(EW) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	**17281.60**	**3.712**	**0.048**	**0.156**	**468**
{*S*(.) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17281.81	3.919	0.044	0.141	467
{*S*(VOLC) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17282.33	4.447	0.033	0.108	468
{*S*(.[gTOWN]) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17282.46	4.575	0.031	0.102	468
{*S*(BUSH) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17282.91	5.026	0.025	0.081	468
{*S*(BOMA) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17283.16	5.276	0.022	0.072	468
{*S*(.[gVOLC]) γ''(g) γ'(g) *p* g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17283.43	5.546	0.019	0.062	468
{*S*(TOWN) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17283.50	5.616	0.019	0.060	468
{*S*(.[gBUSH]) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17283.63	5.742	0.018	0.057	468
{*S*(.[gEWCV]) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17283.79	5.899	0.016	0.052	468
{*S*(.[gEW]) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17283.85	5.967	0.016	0.051	468
{*S*(DICHRO) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17284.02	6.136	0.014	0.047	468
{*S*(VTORT) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17284.08	6.193	0.014	0.045	468
{*S*(.[gBOMA]) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17284.13	6.241	0.014	0.044	468
{*S*(.[gDENS]) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17284.17	6.285	0.013	0.043	468
{*S*(MAXEW) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17284.53	6.638	0.011	0.036	468
{S(EWCV) γ''(g) γ'(g) p(g+t+g:t+gregariousness) c(g+t+g:t+gregariousness)}	17299.05	21.165	0.000	0.000	468
{*S*(g) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17303.05	25.164	0.000	0.000	476
{*S*(.) γ''(g) γ'(g) *p*(g*t) *c*(g*t)}	17335.52	57.634	0.000	0.000	465

[a] g=social community; VDREP=*Vachelia drepanolobium*; VTORT=*Vachelia tortilis*; BETW=betweenness; BOMA=distance (km) to nearest boma; BUSH=deciduous bushlands and thickets; DENS=local adult female giraffe population density; DICHRO=*Dichrostachys cinerea*; EW=mean edge weight; EWCV=edge weight coefficient of variation; GREG=gregariousness (degree); MAXEW=maximum edge weight; TOWN=distance (km) to nearest town; VOLC=volcanic soils.

Table S5. Model selection results for constant survival, community effects, and single, additive, and interactive social and non-social environmental covariate models of apparent adult female survival probabilities among 10 communities of Masai giraffes in the Tarangire Ecosystem, northern Tanzania, 2012–2016 (n = 512 females). Bold are competitive top models (<2 ΔAIC_c).

Model	AIC_c	ΔAIC_c	AIC_c Weights	Model Likelihood	Num. Par
{*S*(GREG+TOWN) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	**17275.20**	**0.000**	**0.285**	**1.000**	**469**
{*S*(GREG*TOWN) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17277.58	2.386	0.086	0.303	470
{*S*(GREG+VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17277.66	2.461	0.083	0.292	469
{*S*(BETW) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17277.89	2.696	0.074	0.260	468
{*S*(GREG+BOMA) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17278.06	2.868	0.068	0.238	469
{*S*(GREG) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17278.79	3.598	0.047	0.166	468
{*S*(BETW+BOMA) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.04	3.843	0.042	0.146	469
{*S*(GREG*VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.11	3.917	0.040	0.141	470
{*S*(VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.52	4.325	0.033	0.115	468
{*S*(BETW+TOWN) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.57	4.372	0.032	0.112	469
{*S*(BOMA) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.65	4.457	0.031	0.108	468
{*S*(TOWN) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.90	4.708	0.027	0.095	468
{*S*(BTWN*TOWN) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17279.98	4.787	0.026	0.091	470
{*S*(GREG*BOMA) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17280.04	4.843	0.025	0.089	470
{*S*(BTWN*VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17280.14	4.944	0.024	0.084	470
{*S*(BETW+VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17280.36	5.160	0.022	0.076	469
{*S*(BTWN*BOMA) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17281.41	6.216	0.013	0.045	470
{*S*(EW) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17281.60	6.404	0.012	0.041	468
{*S*(.) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17281.81	6.610	0.010	0.037	467
{*S*(BOMA+VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17281.85	6.655	0.010	0.036	469
{*S*(BOMA*VDREP) γ''(g) γ'(g) *p*(g+t+g:t+gregariousness) *c*(g+t+g:t+gregariousness)}	17282.07	6.869	0.009	0.032	470

[a] BETW=betweenness; VDREP=*Vachelia drepanolobium*; BOMA=distance (km) to nearest boma; EW=mean edge weight; GREG=gregariousness (degree); TOWN=distance (km) to nearest town.

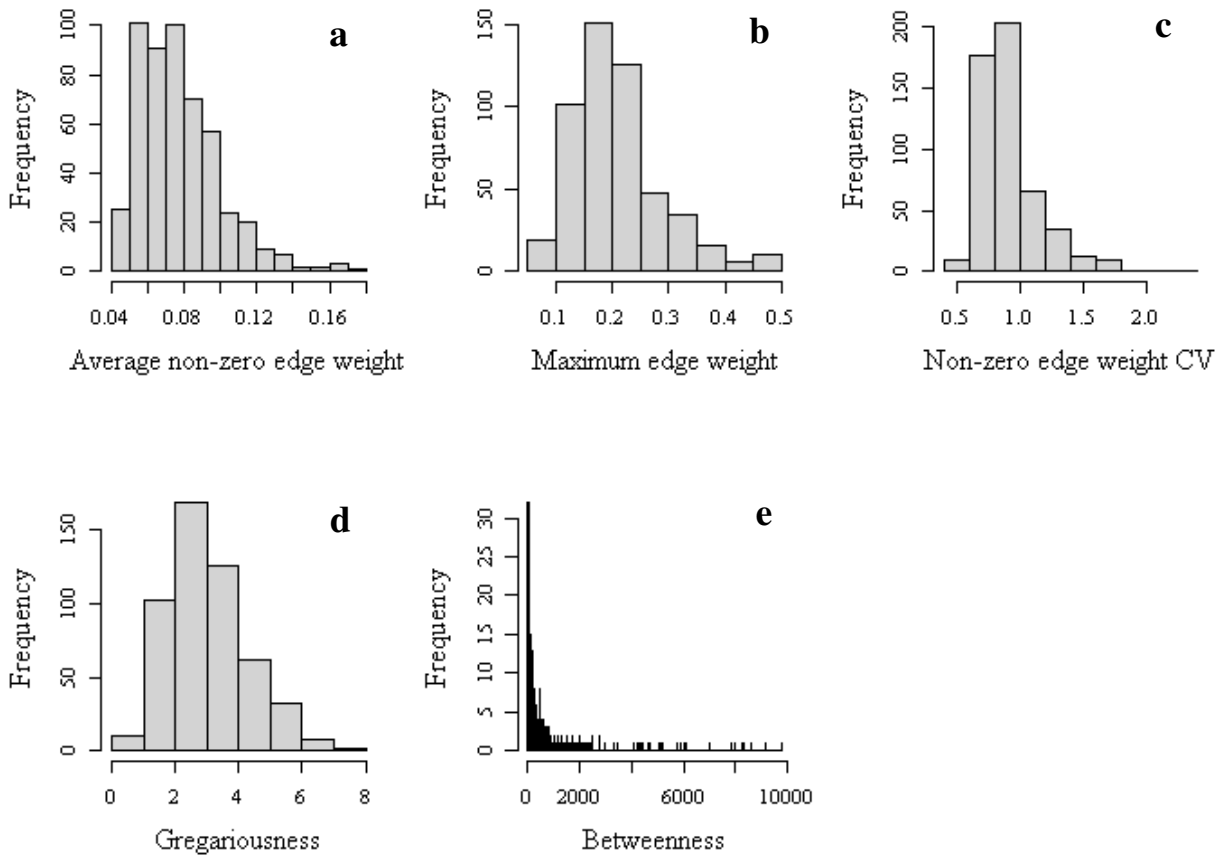

Figure S1. Histograms of the count of values for five measures of sociability among 512 adult female Masai giraffes: (a) average non-zero edge weight [mean relationship strength]; (b) maximum edge weight [maximum relationship strength]; (c) non-zero edge weight coefficient of variation [social exclusivity]; (d) gregariousness; and (e) betweenness.

Figure S2. Two types of human settlements: (a) Masai boma and (b) town. Masai giraffes in two vegetation types in the Tarangire Ecosystem: (c) deciduous bushland and thicket and (d) edaphic grassland on volcanic soils with scattered woody species.

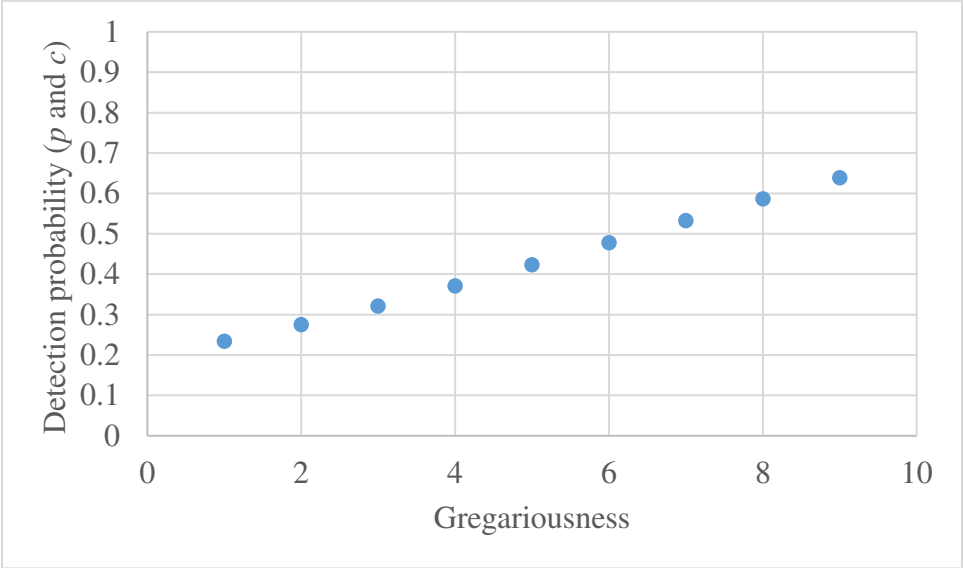

Figure S3. Gregariousness effects in detection probability (capture (p) and recapture probabilities (c)) for 512 adult female Masai giraffes.

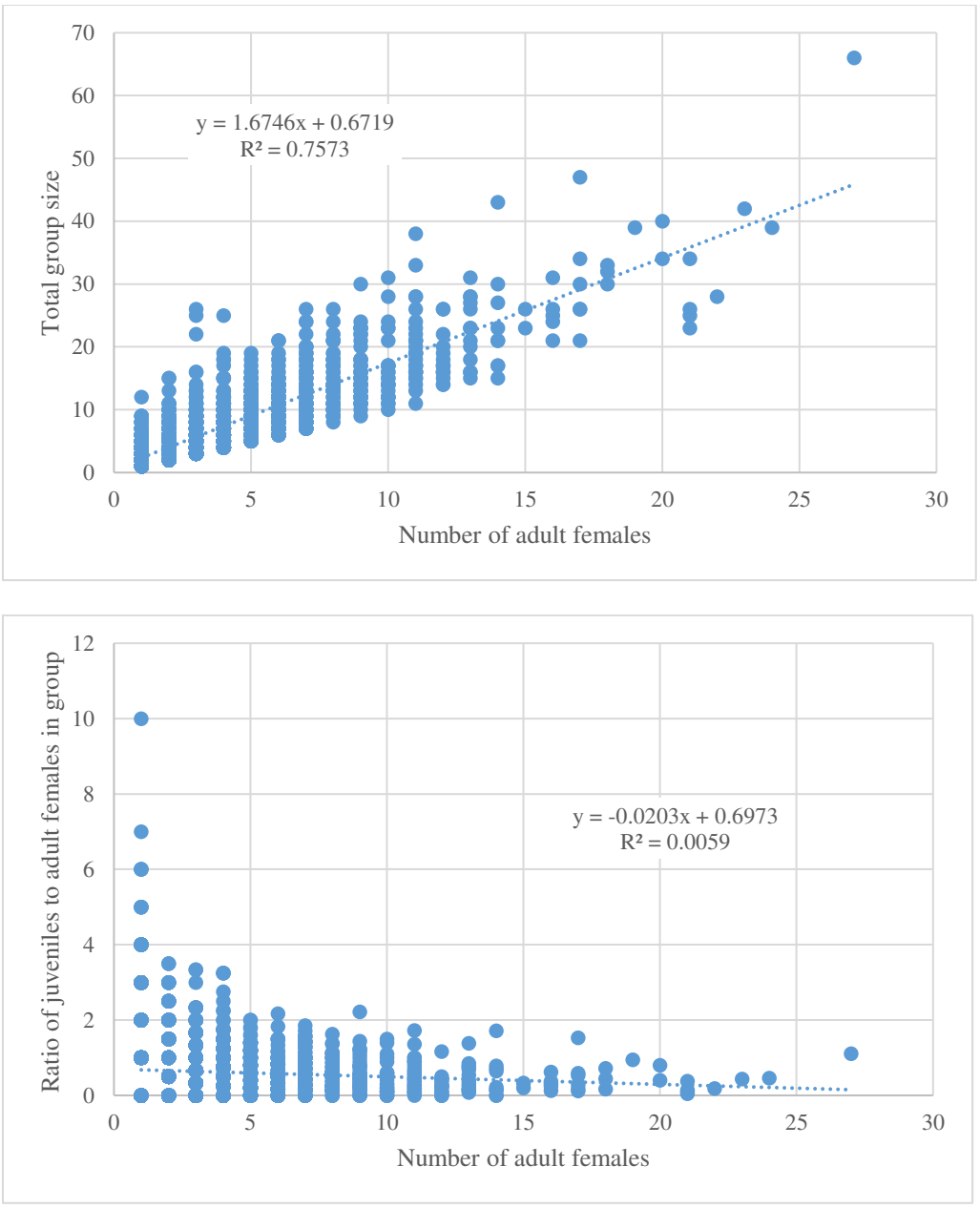

Figure S4. Top shows correlation between number of adult female giraffes in a group with total group size. Bottom shows correlation between number of adult females in a group with ratio of juveniles (calves and subadults) in the group.

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